I. C. 6956 October 1937

DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

COAL-MINE EXPLOSIONS IN OHIO, 1874-1936

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DEPARTMENT OF THE INTERIOR—BUREAU OF MINES

COAL-MINE EXPLOSIONS IN OHIO, 1874-1936[1]

By C. W. Owings[2]

INTRODUCTION

The number of major coal-mine explosions occurring annually in the United States is decreasing, due mainly to fuller recognition of explosion hazards in coal mines and knowledge of methods to prevent them, which can be attributed largely to the dissemination of information by the United States Bureau of Mines, State departments of mines, and other coal-mining agencies. Conditions vary considerably from one coal field to another; consequently, outstanding causes of and methods of combatting explosions vary, also. The Safety Division of the United States Bureau of Mines is making a critical study of coal-mine explosions in the various coal-mining States, and an analysis of the results is published as each study is finished. It is believed that, with completion of the series enough information will be at hand which, if applied, will prevent all coal-mine explosions.

ACKNOWLEDGMENTS

The data in this circular are based on records of the United States Bureau of Mines and the Industrial Commission of Ohio. The cooperation and assistance of T. P. Kearns, superintendent of the Division of Safety and Hygiene of the Industrial Commission of Ohio, and of James Berry, chief inspector of the Division of Mines of Ohio, is acknowledged.

NUMBER OF AND FATALITIES FROM COAL-MINE EXPLOSIONS IN OHIO

Information on Ohio coal-mine explosions is usually meager, in many instances consisting simply of a statement of the number killed, without supporting data. During the 63 years covered by this report, 163 explosions or ignitions are known to have occurred and resulted in the death of 190 and injury to at least 265 persons. The number that escaped uninjured from the

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1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6956."

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sections or mines affected was not ascertainable in most instances; however, at least 209 persons escaped unassisted from mines in which explosions occurred. These data are tabulated in table 1.

Number of explosions

Explosions analyzed by type of mine opening are listed in table 2.

Of the 163 explosions, 134 were caused by gas--85 in shaft mines, 14 in slope mines, and 14 in drift mines; in 21 the openings were not designated. Dust explosions in which, presumably, gas did not play a part were reported nine times--three in shafts, two in slopes, three in drift mines, and one in a mine with an undesignated type of opening. Gas and dust caused seven explosions--four in shaft mines, one in a slope mine, and two in drift mines. So-called "powder smoke", which also may have been gas, caused five explosions--one in a slope mine and four in drift mines. Oil dripping from the roof was ignited and caused an explosion in a shaft mine. Seven explosions were reported in which both the cause and the type of opening were not designated; it appears probable, however, that ignition of gas was the cause of these seven explosions. Of the 163 explosions, 93 were in shaft mines, 18 in slope mines, 23 in drift mines, and 29 in mines in which the type of opening was not designated. Approximately 25 percent of the mines in which explosions occurred are shaft mines, 19 percent slope, and 56 percent drift, based upon type of opening listed in a coal-mine directory. As more than 20 percent of the explosions in mines, the type of opening of which was known, occurred in shaft mines, nearly 14 percent in slope mines, and more than 17 percent in drift mines, evidently the shaft mines are more gassy, as is generally the case, and they also are more hazardous than other types. From 1874 to 1900 approximately 55 percent of the explosions occurred in shaft mines, about 15 percent in slope mines, and about 10 percent in drift mines, indicating that even in the early days coal was extracted from shafts and that gas, probably in small quantities, was encountered and was ignited, usually by open lights.

No explosions occurred in 10 of the 63 years, as follows: 1879, 1880, 1885, 1921, 1924, 1928, 1932, 1933, 1934, and 1936. During the last 6 years only two explosions are reported to have occurred --one in 1931, in which no one was killed, and one in 1935, in which four were killed and two injured. This shows the downward trend of coal-mine explosions in Ohio.

Number of fatalities

During the 63 years studied, 190 persons were reported killed and 265 injured in mine explosions. All of the injuries received during the period 1917-36 resulted from explosions that occurred in only three of the years. Ohio has been relatively free of major explosion disasters, that is, explosions in which five or more men were killed; five such disasters occurred on the following dates: February 10, 1881, April 21, 1910, May 17, 1913, November 5, 1930, and January 3, 1931.

Table 3 lists the number of ignitions and the number killed and injured by explosions, according to type of mine opening. 151 persons (an average of

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TABLE 1. - Gas and dust explosions in Ohio coal mines, 1874-1936

Case no.	Date	County	Type of opening	Men: Average no. employed	Men: In mine	Explosion: Type	Explosion: Extent	Explosion: Limited by-	Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Total for year: No. explosions	Total for year: No. killed	Total for year: No. injured
1	1874 Aug. 18	Mahoning	Shaft	-	-	Gas	Local	-	-	Probably open light.	-	-	0	1	-	1	0	1
2	1875 -	Jackson	do.	-	-	do.	do.	-	-	do.	-	-	0	2	-	1	0	2
3	1876 May 18	-	Slope	-	-	do.	do.	-	-	do.	-	-	0	1	-	2	0	2
4	May 27	-	Shaft	-	-	do.	do.	-	-	do.	-	-	0	2	-			
5	1877 Jan. 31	-	Drift	-	-	do.	do.	-	-	do.	-	-	0	1	-			
6	Mar. 1	Trumbull	-	-	-	do.	do.	-	-	do.	-	-	0	2	-	3	0	5
7	May 22	-	-	-	-	do.	do.	-	-	do.	-	-	0	1	-	1	0	1
8	1878 Mar. 3	-	-	-	-	do.	do.	-	-	-	-	-	-	-	-	-	0	-
	1879 No report	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	1880	-	-	-	-	-	-	-	-	-	-	-	1	-	-			
9	1881 Feb. 10	Columbiana	-	-	-	Gas	Violent	-	Ineffective furnace.	Open light.	Men entered before fireboss' examination.	Increase amount of air.	6	5	-			
10	-	do.	Slope	-	-	do.	Local	-	-	-	-	-	0	4	-			
11	-	Perry	do.	-	-	do.	do.	-	-	-	-	-	0	2	-	3	6	11
12	1882 Aug. 20	Jackson	do.	-	1	do.	do.	-	Furnace damped.	Open light.	No examination; foreman on "other business."	Keep furnace burning rapidly.	1	0	-	1	1	0
13	1883 July 1	Belmont	Drift	-	-	do.	do.	-	Released by fall.	do.	Mine foreman burned, going over fall to rescue injured man.	-	0	1	-			
14	-	Stark	Shaft	-	-	do.	do.	-	Insufficient ventilation.	do.	-	-	0	2	-	2	0	3

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Case no.	Date	County	Type of opening	Men: Average no. employed	Men: In mine	Explosion: Type	Explosion: Extent	Explosion: Limited by	Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Total for year: No. of explosions	Total for year: No. killed	Total for year: No. injured
15	1884 Mar. 31	Athens	Shaft	-	-	Gas	Local	-	-	-	-	-	0	1	-			
16	June 13	Mahoning	do.	-	-	do.	do.	-	-	-	-	-	1	3	-	2	1	4
	1885	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
17	1886 June 24	Lorain	Shaft	-	-	Gas	Local	-	No ventilation.	Open light.	-	-	0	3	-	1	0	3
18	1887 Dec. 19	Guernsey	do.	-	-	Oil	do.	-	-	do.	Petroleum oil dripping from roof ignited.	-	1	1	-	1	1	1
19	1888 Feb. 27	Trumbull	do.	75	-	Gas	do.	-	-	Probably open light.	Men had no business in mine; went into mine to seek work.	-	0	2	-	1	0	2
20	1889 May 19	Athens	do.	199	2	do.	do.	-	Door open.	do.	Door propped open.	-	0	2	-			
21	July 17	Perry	Drift	37	-	do.	do.	-	Poor ventilation.	do.	Needed an air shaft.	Men withdrawn until air shaft sunk.	0	2	-	2	0	4
22	1890 Mar. 27	Columbiana	Shaft	-	-	do.	do.	-	-	do.	-	-	0	2	-			
23	June 22	do.	do.	-	-	do.	do.	-	-	do.	-	-	1	0	-			
24	Dec. 9	Jackson	do.	-	-	do.	do.	-	-	do.	-	-	0	2	-			
25	Dec. 10	Trumbull	Drift	-	-	do.	do.	-	-	do.	-	-	0	1	-	4	1	5
26	1891 Feb. 17	Stark	Shaft	-	-	do.	do.	-	-	do.	-	-	0	1	-			
27	May 19	Jackson	do.	-	-	do.	do.	-	-	do.	-	-	0	1	-			
28	July 1	Athens	do.	-	-	do.	do.	-	-	do.	-	-	0	1	-	3	0	3
29	1892 May 20	Jackson	do.	46	46	do.	do.	-	Brattice not advanced.	do.	Brushing out gas, fireboss failed to examine place (sick).	Advance brattice; must examine places before men enter shaft.	0	2	-			

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30	May 30	Jackson	Shaft	68	68	Gas	Local	-	-	Probably open light.	Entered room "dangered off" by fireboss.	-	1	0	-		
31	-	do.	Slope	68	9	do.	do.	-	-	do.	Examined half hour before; no gas.	-	0	1	-	3	1 3
32	1893 Jan. 31	Perry	Drift	32	-	Dust	do.	-	Blasting.	do.	Blown-out shot.	-	0	2	-		
33	Dec. 7	Jackson	Shaft	76	-	Gas	do.	-	-	do.	-	-	0	2	-	2	0 4
34	1894 June 28	Athens	do.	195	-	do.	do.	-	Fan too small.	do.	Entered an abandoned room.	Larger fan.	0	3	-		
35	July 25	do.	do.	153	-	do.	do.	Natural rock dust	Poor ventilation.	Open light.	Man was climbing over fall.	-	1	0	-	2	1 3
36	1895 Sept. 9	Columbiana	Slope	75	-	do.	do.	-	Blasting.	do.	Brushing out gas	-	0	1	-		
37	Nov. 18	Stark	do.	225	-	do.	do.	-	Poor ventilation.	-	-	Improve ventilation.	0	1	-		
38	Nov. 25	Athens	Shaft	150	-	do.	do.	-	-	-	-	-	0	1	-		
39	Nov. 26	Columbiana	Slope	54	-	do.	do.	-	-	-	-	-	0	1	-		
40	Nov. 28	do.	do.	54	-	do.	do.	-	-	-	-	-	0	1	-	5	0 5
41	1896 May 10	Noble	Shaft	19	1	do.	do.	-	Ventilation suspended.	Open light.	Pump down for 24 hours; exhaust steam used to create ventilation; walked into gas.	-	1	0	-		

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				Average no. employed	In mine	Type	Extent	Limited by-								No. of explosions	No. killed	No. injured
42	1896 Nov. 12	Columbiana	Slope	76	12	Gas	Local	-	No brattice.	Open light.	Fireboss placing brattice; miner ignited gas with open light.	-	0	2	-	2	1	2
43	1897 Jan. 23	Athens	Shaft	90	1	do.	do.	-	Poor ventilation.	Furnace fire.	Gas ignited in furnace while furnace was cleaned out.	-	0	1	-			
44	June 2	Jackson	do.	88	-	do.	do.	-	Entry idle.	Open light.	Men dissatisfied with rooms assigned walked to face of entry and lit gas.	-	0	2	-			
45	Aug. 2	Guernsey	do.	-	2	do.	do.	-	do.	do.	-	-	0	2	-			
46	Sept. 13	Belmont	do.	19	1	do.	do.	-	Fan stopped.	do.	Fan had just been started; no fireboss' examination; passing through door, ignited gas.	Obey law re fireboss examinations before men enter mine.	0	1	-			
47	Dec. 22	Portage	do.	80	-	do.	do.	-	-	do.	Brushing out gas.	-	0	2	-	5	0	8
48	1898 Feb. 18	Stark	do.	84	-	do.	do.	-	Feeder.	do.	do.	Brattice to face.	0	1	-			
49	Feb. 25	do.	do.	84	-	do.	do.	-	do.	Spark from pick.	-	do.	0	1	-			
50	Mar. 15	do.	Slope	100	5	do.	do.	-	-	Open light.	Mine idle; no examination of mine.	No men to enter before fireboss examines mine.	0	3	-			

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Case no.	Date	County	Type of opening	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area unharmed	Total for year		
				Average no. employed	In mine	Type	Extent	Limited by-								No. of explosions	No. killed	No. injured
51	1898 Sept. 3	Guernsey	Shaft	172	-	Gas	Local	-	-	Open light.	-	-	0	1	-			
52	Sept.19	Columbiana	Slope	43	-	do.	do.	-	Cut into abandoned room.	do.	Suffocated from afterdamp from burning well.	-	1	0	-			
53	Oct. 1	Guernsey	Shaft	50	-	do.	do.	-	Abandoned oil well.	do.	Cut into abandoned oil well.	Had been warned; failed to obey.	0	2	-			
54	Nov. 1	Perry	Drift	46	-	Dust	do.	-	-	Blasting.	Overcharged shot	-	0	2	-	7	1	10
55	1899 Jan. 20	Noble	Shaft	59	-	Gas	do.	-	Poor ventilation.	Open light.	No fireboss examination; idle day.	None to enter until fireboss examination completed.	0	1	-			
56	Jan. 21	Stark	do.	87	-	do.	do.	-	-	do.	Air shaft in poor condition.	Repair shaft.	0	1	-			
57	Mar. 4	Guernsey	do.	395	-	do.	do.	-	-	do.	-	-	0	1	-			
58	1899 Mar. 13	Jackson	do.	117	-	do.	do.	-	-	do.	-	-	0	3	-			
59	Mar. 19	Noble	do.	59	-	do.	do.	-	Door open.	do.	No fireboss; idle day.	None to enter before fireboss examines.	0	2	-			
60	Nov. 11	Stark	do.	134	-	do.	do.	-	-	do.	-	-	0	2	-			
61	Dec. 2	Guernsey	do.	113	-	do.	do.	-	-	do.	-	-	0	2	-	7	0	12
62	1900 Apr. 16	Stark	do.	147	-	do.	do.	-	-	do.	-	-	0	1	-			
63	June 8	Athens	do.	190	3	do.	Extensive	-	Fire.	Fire.	-	Stop leaks in "walls."	3	0	-	2	3	1
64	1901 Feb. 8	Stark	do.	147	-	do.	Local	-	-	Open light.	-	-	0	1	-			
65	Sept.25	Jefferson	do.	159	-	do.	do.	-	-	do.	-	-	0	1	-			

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66	1901 Sept. 27	Jackson	Shaft	100	-	-	-	-	-	-	-	-	1	0	-			
67	Nov. 4	Columbiana	Slope	65	-	Gas	Local	-	-	Open light.	-	-	0	1	-			
68	Nov. 11	Jefferson	Shaft	3	3	do.	Violent	To surface	Dewatering shaft.	Electricity	75,000 cu.ft.air per min. but there may have been a pocket lighted by electric spark.	-	3	0	-	5	4	3
69	1902 Mar. 2	Guernsey	do.	115	-	do.	Local	-	-	do.	-	-	0	1	-			
70	June 20	Tuscarawas	Drift	95	-	Dust	do.	-	Blasting.	Black powder.	Shots fired too rapidly in succession.	-	0	5	-			
71	Aug. 5	Athens	Shaft	245	-	Gas	do.	-	-	-	-	-	0	1	-			
72	Oct. 13	Perry	Slope	83	-	do.	do.	-	-	-	-	-	0	1	-			
73	Nov. 2	Hocking	Drift	135	3	do.	-	-	Unventilated section.	Fire.	Fall tore down brattice; let in fresh air.	-	3	0	-			
74	Dec. 27	Tuscarawas	do.	155	-	Powder smoke	-	-	-	-	-	-	0	1	-	6	3	9
75	1903 Jan. 29	Jackson	Shaft	102	-	Gas	Local	-	-	-	-	-	0	1	-			
76	Apr. 17	Tuscarawas	Drift	103		Powder smoke	do.	-	-	-	-	-	0	3	-			
77	June 16	Jackson	Shaft	102	-	Gas	do.	-	-	-	-	-	0	1	-			
78	Sept. 21	Jefferson	do.	123	-	do.	do.	-	Ventilation sluggish.	(Flame lamp) Match.	Careless with safety lamp; man warned not to strike match.	Ventilation should be improved; brattices should be tightened.	2	7	-			

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79	1903 Oct. 14	Guernsey	Shaft	290	-	Gas	Local	-	Fall.	Open light.	-	-	2	0	-			
80	Oct. 31	Columbiana	Slope	60	-	Powder smoke	do.	-	Blasting.	Black powder.	Leaky brattice; shots fired at once; ignited smoke.	Employ shot firers.	0	10	-	6	4	22
81	1904 Mar. 24	Guernsey	Shaft	94	90	Gas	One section	-	Fall in room.	Open light.	Caved room dangered off; miner disobeyed orders.	Precautions along every line.	0	6	-			
82	Apr. 29	Athens	do.	-	-	do.	-	-	-	-	-	-	0	1	-			
83	Sept. 26	Jackson	do.	35	-	do.	-	-	Poor ventilation.	Open light.	Doors and brattices in need of repair.	Employ a fireboss.	0	1	-			
84	Dec. 9	Guernsey	do.	94	2	do.	One section	-	"Unexpected."	do.	Obstruction.	Remove obstruction in air course.	0	2	-			
85	-	Noble	do.	190	-	do.	-	-	-	do.	-	-	0	2	-	5	0	12
86	1905 May 30	Perry	do.	202	1	do.	One section	-	Fan stopped.	do.	Fan stopped 15 min.; fireboss carrying flame safety lamp and open light; passed damaged brattice.	Keep fan running at greater speed.	1	0	-			
87	-	Athens	-	-	-	do.	-	-	-	-	-	-	0	1	-			
88	-	-	-	-	-	-	-	-	-	-	-	-	0	1	-	3	1	2

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89	1906 July 18	Jefferson	Shaft	6	8	Gas	500 ft.	To surface	Poor ventilation.	Open light.	Mine foreman, with mine inspector, lit gas with open light; had not lit flame safety lamp.	Build brick stoppings; connect two single entries and use double-entry system; provide adequate fan.	0	2	-			
90	Aug. 6	Belmont	Slope	7	-	do.	Local	-	do.	do.	Miner warned not to come up room as gas was at face; disregarded warning; lit gas.	Mine shut down as owner knew little about gas.	2	0	-			
91	Aug. 29	Athens	Shaft	-	-	do.	500 ft.	To surface	Fan stopped for 8 hrs.	do.	Fan started but had not moved gas; men placed lamps 40 ft. from face and brushed out gas which was lit by lamps.	Partition shaft and install larger fan; make parallel entry.	2	1	-			
92	Oct. 25	Tuscarawas	Drift	95	-	Gas and dust	Local	-	Blasting.	Blasting.	Had fired too many shots; afterdamp suffocated men.	Breakthroughs in rooms at 30' and 60'; reduce quantity of explosives.	3	0	-			

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Case no.	Date	County	Type of opening	Men: Average no. employed	Men: In mine	Explosion: Type	Explosion: Extent	Explosion: Limited by-	Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Total for year: No. of explosions	Total for year: No. killed	Total for year: No. injured
93	-	Columbiana	Shaft	44	-	Powder smoke	Local	-	Blasting.	Blasting.	-	-	0	3	-			
94	-	Guernsey	do.	150	-	Gas	do.	-	Fall of roof.	Open lights.	Attempting to cross fall in caved room to get tools.	-	0	3	-	6	7	9
95	1907 Jan. 2	do.	Slope	118	-	do.	do.	-	do.	do.	do.	-	0	1	-			
96	Mar. 23	Athens	Shaft	248	15	do.	Extensive	-	Door open.	do.	Mine not thoroughly examined; ventilation deranged.	Improve ventilation; inspect all of mine before shift enters.	3	5	7			
97	May 20	Jefferson	do.	200	-	do.	Local	-	"Blower."	do.	One of fans not operating.	Operate both fans; pumper to carry flame safety lamp.	0	1	-			
98	June 25	Tuscarawas	Drift	117	117	Powder smoke	do.	-	Blasting.	Explosives.	Fired 8 shots simultaneously.	Limit charge; last man on split to blast first.	0	5	-			
99	Aug. 19	Guernsey	Shaft	204	-	Gas	do.	-	-	Probably open light.	"Face, hand, and side burned by gas."	-	0	2	-			

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TABLE 1. - Gas and dust explosions in Ohio coal mines, 1874-1976 - Continued

Case no.	Date	County	Type of opening	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Total for year		
				Average no. employed	In mine	Type	Extent	Limited by-								No. of explosions	No. killed	No. injured
100	-	Columbiana	-	-	-	Gas	-	-	-	-	-	-	0	1	-	6	3	15
101	1908 May 27	do.	Shaft	172	-	do.	Extensive	To surface	Fan stopped.	Open light.	Rescuer killed by falling timber.	Use safety lamps; keep fan running continuously; erect new slow-speed fan at top of shaft.	2	1				
102	Aug. 10	Jefferson	Drift	12	-	do.	-	-	-	-	-	-	0	2	-			
103	Oct. 17	Columbiana	do.	282	-	do.	Local	-	Fan stopped.	Open light.	Entries connected to old entries; fan just started.	Install engine (for ventilation) and ventilation pipe.	0	3	-			
104	Dec. 8	Guernsey	Shaft	169	-	do.	do.	-	Fall.	do.	Mine idle 3 days; no fireboss exam.; fan stopped for 2 hours.	Place check on entry; ventilate 2 rooms; make preshift exam.	0	2	-			
105	1908 -	Athens	-	-	-	do.	do.	-	-	-	-	-	0	1	-			
106	-	Noble	-	-	-	do.	do.	-	-	-	-	-	0	1	-			
107	-	Portage	-	-	-	do.	do.	-	-	-	-	-	0	1	-	7	2	11

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TABLE 1. - Gas and dust explosions in Ohio coal mines, 1874-1936 - Continued

Case no.	Date	County	Type of opening	Men: Average no. employed	Men: In mine	Explosion: Type	Explosion: Extent	Explosion: Limited by-	Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from mine uninjured	Total for year: No. of explosions	Total for year: No. killed	Total for year: No. injured
108	1909 Feb. 5	Noble	Shaft	59	-	Gas	Local	-	-	Open light.	Mine idle while making a second opening.	Examine any section with flame safety lamp before entering with open light.	0	1	-			
109	Mar. 15	Portage	do.	84	-	do.	do.	-	Feeder.	do.	Cut into fault.	Exercise care when approaching a fault.	0	3	-			
110	Apr. 19	Belmont	do.	31	-	do.	do.	-	Poor ventilation.	do.	Gas found; opened compressed air valve; no danger board.	Enforce fireboss' duties; make fireboss examine and have mine free of gas before men enter mine.	0	6	-			
111	July 21	do.	do.	31	1	do.	do.	-	Fan stopped.	do.	Supt. started fan and then entered mine.	-	1	0	-			
112	Aug. 13	Guernsey	do.	237	-	do.	do.	-	-	do.	-	-	0	3	-			
113	Nov. 4	Columbiana	Drift	66	-	do.	do.	-	-	do.	-	-	0	1	-			
114	Nov. 22	Belmont	do.	312	-	do.	do.	-	Fan stopped.	do.	Fan stopped for 24 hours; cut into clay vein; entries rising.	Men must not enter mine when fan is not running.	0	2	-			

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TABLE 1. - Gas and dust explosions in Ohio coal mines, 1874-1936 - Continued

Case no.	Date	County	Type of opening	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area unharmed	Total for year		
				Average no. employed	In mine	Type	Extent	Limited by-								No. of explosions	No. killed	No. injured
115	1909 Dec. 16	Columbiana	Slope	47	2	Dust	Extensive	-	Blasting.	Explosives.	Kegs of black blasting powder also exploded.	Use incombustible stemming; use permissible explosives; clean out dust; sprinkle entries and room necks; undercut coal; no holes on solid.	2	0	-	8	3	16
116	1910 Jan. 24	do.	do.	47	1	do.	do.	-	do.	do.	Holes on solid; no undercutting.	Undercut coal before blasting; no solid shooting; use permissible explosives.	1	0	-			
117	Mar. 9	Jefferson	Shaft	210	0	Gas	Local	-	-	Fire.	Black blasting powder ignited gas.	-	0	0	0			
118	Apr. 21	do.	do.	160	23	Gas and dust	do.	-	Open door.	Open light.	Driver propped open one or more doors.	Construct masonry stoppings; install automatic doors; sprinkle and remove dust.	15	3	5			

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Case no.	Date	County	Type of opening	Men: Average no. employed	Men: In mine	Explosion: Type	Explosion: Extent	Explosion: Limited by-	Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Total for year: No. of explosions	Total for year: No. killed	Total for year: No. injured
119	1910 June 13	Guernsey	Shaft	215	200	Gas	Local	-	-	-	-	-	0	1	-			
120	Sept. 12	Jackson	do.	61	-	do.	do.	-	-	Open light.	-	-	1	0	-			
121	Dec. 2	Belmont	Drift	314	-	do.	do.	-	-	do.	-	-	0	2	-			
122	-	Athens	-	-	-	do.	do.	-	-	-	-	-	0	1	-			
123	-	Jackson	-	-	-	do.	do.	-	-	-	-	-	0	1	-	8	17	8
124	1911 Jan. 13	Noble	Shaft	161	-	do.	do.	-	-	-	-	-	0	1	-			
125	Feb. 27	do.	do.	161	-	do.	do.	-	-	-	-	-	0	1	-			
126	Mar. 10	Jefferson	do.	224	-	do.	do.	-	-	-	-	-	0	1	-			
127	Apr. 22	Athens	do.	339	-	do.	do.	-	-	-	-	-	0	1	-			
128	Oct. 5	Portage	do.	75	-	do.	do.	-	-	-	-	-	0	1	-			
129	Dec. 7	Guernsey	do.	280	-	do.	do.	-	-	-	-	-	0	2	-	6	0	7
130	1912 Feb. 20	Noble	do.	230	-	do.	do.	-	Fall.	Open light.	Started over fall with safety and open lights.	-	1	2	-			
131	Mar. 10	Belmont	Drift	134	-	do.	do.	-	Fan stopped.	do.	Fan stopped; started over fall, open light ignited gas.	-	0	1	-			
132	May 5	Columbiana	do.	23	-	do.	do.	-	-	do.	Deficient ventilation.	-	0	1	-			
133	Dec. 29	Belmont	Slope	156	-	Gas and dust	do.	-	Fan stopped.	do.	Men entered mine before power was turned on.	-	1	1	-	4	2	5

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TABLE 1. - Gas and dust explosions in Ohio coal mines, 1874-1936 - Continued

Case no.	Date	County	Type of opening	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from mine uninjured	Total for year		
				Average no. employed	In mine	Type	Extent	Limited by-								No. of explosions	No. killed	No. injured
134	1913 May 17	Jefferson	Shaft	150	-	Gas and dust	-	-	Door open.	Open light.	No fireboss examination; new parting being constructed; door and brattice left open.	Clean air courses; construct air-tight noncombustible stoppings.	15	1	6			
135	Nov. 1	Perry	do.	384	36	Gas	Local	-	-	Fire.	Two explosions occurred.	Mine be sealed.	0	3	33			
136	Nov. 12	do.	do.	150	-	do.	do.	-	Fall.	Open light.	Fall caused stopping to leak.	-	0	1	-			
137	Nov. 15	Belmont	Drift	49	-	do.	do.	-	Old works.	do.	Mining machine cut into old workings.	-	0	0	-	4	15	5
138	1914 Jan. 27	do.	do.	165	-	Gas and dust	do.	-	Open door.	do.	Explosion limited by natural shale present.	Preshift examination for firedamp.	1	0	-			
139	June 14	Jefferson	Shaft	179	0	Gas	do.	-	Fan stopped.	do.	Fan idle 16 days; men in shaft; gas ignited in fan house.	Make haulage roads intakes; seal abandoned workings.	0	2	0	2	1	2
140	1915 -	Belmont	-	-	-	do.	-	-	-	-	-	-	0	1	-			
141	-	Guernsey	-	-	-	-	-	-	-	-	-	-	0	3	-			
142	-	Jefferson	-	-	-	-	-	-	-	-	-	-	0	2	-			

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TABLE 1. - Gas and dust explosions in Ohio coal mines, 1874-1936 - Continued

Case no.	Date	County	Type of opening	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area unaffected	Total for year		
				Average no. employed	In mine	Type	Extent	Limited by-								No. of explosions	No. killed	No. injured
143	1915 -	Stark	-	-	-	-	-	-	-	-	-	-	0	1	-	4	0	7
144	1916 -	Belmont	-	-	-	-	-	-	-	-	-	-	0	3	-			
145	-	Guernsey	-	-	-	-	-	-	-	-	-	-	0	2	-			
146	-	Jefferson	-	-	-	-	-	-	-	-	-	-	0	1	-			
147	-	Tuscarawas	-	-	-	-	-	-	-	-	-	-	0	2	-	4	0	8
148	1917 -	Jefferson	-	-	-	Gas	-	-	-	-	-	-	1	0	-	1	1	0
149	1918 -	-	-	-	-	do.	-	-	-	-	-	-	2	0	-	1	2	0
150	1919 -	-	-	-	-	do.	-	-	-	-	-	-	2	0	-	1	2	0
151	1920 -	-	-	-	-	do.	-	-	-	-	-	-	3	0	-	1	3	0
	1921 -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
152	1922 -	Belmont	-	-	-	Gas	-	-	-	-	-	-	1	0	-	1	1	0
153	1923 -	Monroe	-	-	-	do.	-	-	-	-	-	-	2	0	-	1	2	0
	1924 -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
154	1925 Jan. 10	Belmont	Shaft	210	5	Dust	Extensive	-	-	Electric arc.	Stray current ignited 41 kegs black blasting powder.	Use permissible explosives; rock dust.	4	0	1	1	4	0
155	1926 -	do.	-	-	-	do.	-	-	-	-	-	-	1	0	-			
156	Feb. 15	do.	Shaft	600	600	do.	Local	-	Dumping coal.	Electric arc.	Dust on tipple and in shaft ignited by motor in tipple.	Remove dust on tipple daily; use permissible elec. equipment.	1	23	-	2	2	23

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TABLE 1. - Gas and dust explosions in Ohio coal mines, 1874-1936 - Continued

Case no.	Date	County	Type of opening	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Total for year		
				Average no. employed	In mine	Type	Extent	Limited by-								No. of explosions	No. killed	No. injured
157	1927 -	Belmont	-	-	-	Gas	-	-	-	-	-	-	1	0	-	1	1	0
	1928 -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
158	1929 July 9	Belmont	Shaft	3	1	Gas and dust	Local	-	Fan belt slipping.	Electric arc.	Only one opening; fan underground.	Place fan on surface; provide 2 openings.	1	0	0			
159	-	Athens	-	-	-	Gas	-	-	-	-	-	-	1	0	-	2	2	0
160	1930 Nov. 5	do.	Shaft	225	222	do.	Local	Expansion natural inert	Air short-circuited.	Electric arc.	Fall of rock short-circuited wire.	Eliminate doors; rock-dust thoroughly; provide sectional switches.	82	0	119	1	82	0
161	1931 Jan. 3	Tuscarawas	Drift	50	19	Dust	do.	-	Blasting.	Pellet powder.	Hole drilled 28" on solid; "bug-dust" stemming.	Rock-dust mine; wet coal and dust; use permissible explosives.	5	4	14	1	5	4
	1932	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	1933	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	1934	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0

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TABLE 1. - Gas and dust explosions in Ohio coal mines, 1874-1936 - Concluded

I. C. 6956

Case no.	Date	County	Type of opening	Men		Explosion			Cause of accumulation	Source of ignition	Other factors	Recommendations made	Killed	Injured	Escaped from area uninjured	Total for year		
				Averages no. employed	In mine	Type	Extent	Limited by-								No. of explosions	No. killed	No. injured
162	1935 Oct. 14	Jefferson	Drift	-	-	Gas	Local	-	Mining machine cut feeder.	Open light.	Machineman ignited gas with open light.	-	0	0	0			
163	Dec. 5	do.	Shaft	290	30	Gas and dust	do.	-	Interrupted ventilation.	do.	Line brattice too far from face; blasting released gas.	Use permissible explosives, lights, and electrical equipment; provide adequate ventilation; use air locks.	4	2	24	2	4	2
	1936 -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Total													190	265	209	163	190	265

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TABLE 2. - Type of explosion by type of mine opening

Type of explosion	Total	Shaft	Slope	Drift	Undesignated
Gas	134	85	14	14	21
Dust	9	3	2	3	1
Gas and dust	7	4	1	2	0
"Powder smoke" ..	5	0	1	4	0
Oil	1	1	0	0	0
Not designated ..	7	0	0	0	7
Totals	163	93	18	23	29

TABLE 3. - Explosion fatalities and ignitions by type of mine opening

Type of opening	Number of ignitions	Killed		Injured	
		No.	Average per ignition	No.	Average per ignition
Shaft	93	151	1.6	164	1.8
Slope	18	7	.4	29	1.6
Drift	23	12	.5	40	1.7
Not designated .	29	13	.6	32	1.1
Totals	163	190	1.2	265	1.6

1.6 per ignition) were killed in shaft mines, and 164 (an average of 1.8 per ignition) were injured; 7 (an average of 0.4 per ignition) were killed in slope mines and 29 (an average of 1.6 per ignition) were injured; 12 (an average of 0.5 per ignition) were killed in drift mines and 40 (an average of 1.7 per ignition) were injured. An average of 1.2 persons was killed and 1.6 injured per explosion, or an average of 2.8 killed and injured per explosion.

Explosion fatalities and injuries are given by counties in table 4. The greatest number of ignitions occurred, in decreasing order, in the following counties: Belmont, 19 explosions; Athens, Columbiana, and Guernsey, 18 explosions each; Jackson, 17 explosions; and Jefferson, 15 explosions. The greatest number of fatalities (92), with 21 persons injured, was caused by 18 explosions in Athens County, an average of more than 5 killed and 1 injured for each explosion. Jefferson County ranked second in the number of explosion fatalities, (39) with 25 persons injured, an average of more than 2.5 killed and 1.7 injured per explosion. The largest number of persons (41) was injured, in the 19 explosions in Belmont County.

Ohio coal-mine-explosion fatality rates per million tons produced and man-hours worked are given in table 5 by 10-year periods from 1874 to 1933, inclusive, and for single years for 1934, 1935, and 1936. The rates per period fluctuate considerably, ranging from 0 to 0.440 death per million tons of coal mined. The latter figure was influenced by an explosion in which 82 persons were killed. The fatality rate based on the exposure of employees to accidents ranges from 0 to 0.253, the larger figure again being

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TABLE 4. - Explosion fatalities and injuries, by counties

County	Number of ignitions	Fatalities	Injuries
Athens	18	92	21
Belmont	19	14	41
Columbiana	18	13	34
Guernsey	18	3	31
Hocking	1	3	0
Jackson	17	4	22
Jefferson	15	39	25
Lorain	1	0	3
Mahoning	2	1	4
Monroe	1	2	0
Noble	10	2	17
Perry	8	1	13
Portage	4	0	7
Stark	11	0	15
Trumbull	3	0	4
Tuscarawas	7	8	20
Not designated	10	8	8
Totals	163	190	265

TABLE 5. - Coal-mine-explosion fatality rates in Ohio, 1874-1936

Period	Fatality per million tons	Fatality per million man-hours	Percent of explosion fatalities to total coal-mine deaths
1874-1883	0.114	1/ 0.030	3.21
1884-1893	.038	.010	1.13
1894-1903	.100	.038	2.74
1904-1913	.167	.074	3.76
1914-1923	.035	.016	1.08
1924-1933	.440	.253	12.31
1934	.000	.000	.00
1935	.194	1/ .113	4.04
1936	.000	.000	.00

1/ Estimated.

affected by the explosion in which 82 deaths occurred. In general, the explosion-fatality rates in Ohio are based on figures furnished to the United States Bureau of Mines on underground accidents, and explosion fatalities in Ohio were much fewer than the average for the coal mines of the United States as a whole. In the 5-year period 1911-15, Ohio had an explosion-fatality rate, based on underground fatalities, of 0.068 death per million man-hours, compared with 0.313 per million man-hours for the United States. In the next 5-year period, 1916-20, the rate in Ohio was 0.026 per million man-hours, and in the United States 0.180. In the 5 years 1921-25, the rates were 0.013 death per million

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man-hours in Ohio and 0.347 per million man-hours in the United States. Due to a disastrous explosion in 1930, the rate for Ohio from 1926-30 was 0.601 compared with 0.341 fatality per million man-hours in the United States. The average rate for the 15 years from 1911-25, inclusive, was 0.036 death per million man-hours in Ohio and 0.280 death per million man-hours in the United States.

Explosions caused 0 to 12.31 percent of all coal-mine deaths during the 63-year period. In the 10 years 1924-33, in which one explosion caused 83 fatalities, 12.31 percent of the fatalities was due to mine explosions. In the preceding 10 years the percentage was 1.08, and in the 3 years following 1933 the rate averaged 1.35 percent of all coal-mine deaths.

CAUSES OF COAL-MINE EXPLOSIONS IN OHIO

Most of the explosions were caused by open-flame lights. According to table 6, open lights caused 91 ignitions (55.83 percent of all ignitions), and flame safety lamps, furnace fire, and a match caused one explosion each (0.61 percent of the ignitions being due to each cause). Open flames caused a total of 94 ignitions, representing 57.67 percent of the explosions.

TABLE 6. - Alleged or probable causes of ignitions

Cause	Number of ignitions	Percent of ignitions
Open flames:		
Open lights	91	55.83
Flame safety lamp	1	.61
Furnace fire	1	.61
Match	1	.61
Total open flames	94	1/ 57.67
Blasting	9	5.56
Electricity	6	3.68
Fire	4	1/ 2.46
Spark from pick	1	.61
Not designated	49	30.06
Total ignitions	163	100.00

1/ Adjusted.

Blasting was second, with nine explosions (5.56 percent of the total); electricity caused six ignitions (3.68 percent of the total); fires caused four explosions (2.46 percent of the total); and sparks from a pick are said to have caused one explosion (0.61 percent of the total ignitions). The cause of 49 explosions, representing nearly a third of all reported, was not designated, but it is believed that a large number of them resulted from

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ignition of gas by open lights; this belief is based on the cause of explosions occurring under somewhat similar conditions at about the same time.

Causes and percentages of explosions, by periods from 1874 to 1936, are listed in table 7. During the 13-year period 1874-86, 13 explosions, representing 76.47 percent of all the explosions in that period, were caused by open lights. During the next 10-year period 21 explosions, representing 84 percent of the total explosions in that period, were initiated by open lights. During the 10 years 1897-1906, 53 explosions occurred, 32 of which (61.64 percent) were caused by open lights. However, the largest number of explosions (53) occurred during the following 10 years, 1907-16, 26 (49.06 percent) of which were caused by open lights. No explosions were caused by open lights during 1917-26, but in the following 10 years, 1927-36, two explosions (28.67 percent of the seven explosions that occurred in that period) were caused by open lights.

The first explosions caused by blasting were reported during 1897-1906, when five explosions (9.61 percent of the 52 explosions) occurred. In the next 10 years only three explosions (5.66 percent) were caused by explosives. Blasting caused no explosions in the period 1917-26 and only one in the following 10-year period, representing 14.29 percent of the explosions of that 10-year period.

The first ignition attributed to electricity occurred on November 11, 1901; during 1897-1906, two explosions (3.85 percent of all ignitions) were initiated by electricity. No electrical ignitions occurred during the next 10 years, but in each of the following 10-year periods, 1917-26 and 1927-36, two explosions (22.22 and 28.67 percent, respectively, of all ignitions) were of electrical origin.

Fires caused four explosions (3.85 percent of the total ignitions), two of them occurring between 1897 and 1906; and in the following 10-year period two more explosions (2.77 percent of all ignitions) were caused by fires.

PRINCIPAL CONTRIBUTING CAUSES OF EXPLOSIONS

The exact cause of an explosion is not always readily discernible, as three or four closely related causes may have been responsible. Although the largest number of explosions was attributed to ignitions by open lights, the causes that led to accumulation of gas and dust and other factors entering into the ignitions varied. The principal contributing factors are listed in table 8.

Ventilation

Ventilation deficiencies constituted the chief factor contributing to explosions in Ohio as well as in most of the other coal-producing States of the Union. Among the causes attributed to ventilation defects were: Fans stopped contributed to seven explosions; doors propped open, to three explosions; brattices leaking or too short, to three explosions. The following each contributed to one explosion: Door in need of repairs, lack of air

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TABLE 7. - Causes and percentages of explosions, by periods, 1874-1936

Period	Open lights		Blasting		Electricity		Fires		All others		Total	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
1874-1886 1/	13	76.47	0	-	0	-	0	-	4	23.53	17	100
1887-1896	21	84.00	0	-	0	-	0	-	4	16.00	25	100
1897-1906	32	61.54	5	9.61	2	3.85	2	3.85	11	21.15	52	100
1907-1916	26	49.06	3	5.66	0	-	2	3.77	22	41.51	53	100
1917-1926	0	-	0	-	2	22.22	0	-	7	77.78	9	100
1927-1936	2	28.57	1	14.29	2	28.57	0	-	2	28.57	7	100
Total	94	57.67	9	5.56	6	3.68	4	2.46	50	30.67	163	100

1/ 13-year period.

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TABLE 8. - Factors contributing to causes of explosions

Causes	No. of ignitions
Ventilation defects:	
Fan stopped	7
Door propped open	3
Brattices leaking or too short	3
Door needed repairs	1
Air shaft needed	1
Air shaft in poor condition	1
Pump stopped, no exhaust steam	1
Pocket of gas in ventilated shaft	1
Fall tore down brattice; let in air	1
Deficient ventilation	1
	20
Blasting:	
Too many shots fired	3
Holes on solid	2
Blown-out shot	1
Overcharged shot	1
Shots fired too rapidly	1
Kegs of black blasting powder ignited	1
Black blasting powder ignited gas	1
Stray current ignited 41 kegs of black blasting powder	1
	11
Ineffective or no fireboss examination:	
No fireboss' examination	5
Men entered before fireboss' examination	4
No gas found by fireboss	1
	10
Disobedience or breaking of law:	
Passed danger board (disobeyed warning)	3
Men had no business in mine (visitors)	1
Entered abandoned mine	1
Fireboss erecting brattice; miner disobeyed command	1
Men left assigned rooms; went to entry face	1
Machineman disregarded warning; cut into well	1
	8
Brushing out gas	5
Men going over falls, wearing open lights	5
Failures of officials:	
Officials carrying flame safety lamps and open lights	3
Gas found; no "danger" board placed	1
Official struck match to light flame safety lamp	1
	5
Cut into fault or old workings	2
Oil dripping from roof	1
Gas ignited by furnace during cleaning	1
Afterdamp from burning oil well	1
Rescuer killed by falling timber	1
Fall of rock short-circuited electric wire	1
Machineman ignited gas with open light	1
Dust on tipple from dumping coal	1

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shaft or air shaft in poor condition, pump stopped and no exhaust steam to supply ventilation, pocket of gas in ventilating shaft, fall that tore down brattice and let in air, and "deficient" ventilation. Ventilation deficiencies contributed directly or indirectly to 20 of the ignitions.

Blasting

Blasting was the second most common cause contributing to explosions, explosives having been involved directly or indirectly in 11 explosions. Too many shots fired in close succession caused three explosions, caused principally by an accumulation of so-called "powder smoke." Holes drilled on the solid, loaded with nonpermissible explosives, and fired resulted in ignition of dust, "powder smoke", or gas in two explosions. Blown-out shots were responsible for only one ignition, although overcharged shots and shots fired too rapidly are listed as causing one explosion each. Probably all three of these explosions were due to so-called "blown-out" or "windy" shots. Kegs of black blasting powder ignited in a manner not specified caused one explosion; burning black blasting powder ignited gas in another explosion; and a stray current was reported to have ignited 41 kegs of black blasting powder, causing one explosion.

Ineffective or No Fireboss' Examination

Ten explosions were attributed directly to improper examination or lack of examination of working places by firebosses. Five explosions occurred where no fireboss' examinations had been made, four where men entered the mine before the fireboss made his examination, and one where the fireboss had made an examination without detecting gas.

Disobedience or Breaking of Law

Probably a large number of failures of employees should be classed under this heading; however, only those directly so classed are grouped thereunder. In three explosions men passed the danger board (in at least one explosion in spite of warning). One explosion was caused by nonemployees who entered to see the mine foreman about employment. In another instance, although warned not to do so, men entered an abandoned mine while the fireboss was placing brattice to remove gas, and ignited the gas. In still another instance, men left the room that had been assigned to them, because they did not like the working conditions, and went to the face of an entry to look for a better place; their open lights ignited gas. Disobeying the warning of the hazards from an oil well, machinemen cut into it, and released some gas that was ignited by their open lights. Stopping of the fan contributed to seven explosions. Brushing out gas and men going over falls with open lights each caused five explosions; these are not specified as disobedience or breaking of the law, but they border closely on disregard of laws and regulations and common-sense procedure.

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Failures of Officials

Officials are rarely free from blame for mine accidents, although this attitude is far too often taken by those investigating accidents. In three instances, officials carrying flame safety lamps and wearing open lights ignited gas with the open lights. Another explosion was caused by failure of officials to place a danger board at the entrance to a place where gas had been found. In another instance, gas was ignited by an official, the light of whose flame safety lamp had been extinguished and who ignited gas when he moved back to a place where he thought there was no gas and attempted to light his lamp with a match. All of the five failures of officials to use anything like good judgment resulted in explosions.

Miscellaneous

Among the unclassified factors that contribute to explosions are cut into fault or workings; oil dripping from roof; gas ignited by furnace during sealing; gases from burning oil wells; rescuer killed by falling timber; fall of rock short-circuited electric wire; machineman ignited gas with open light; and dust on tipple from dumping coal. This latter caused an explosion in the tipple of one mine, and the flame was transmitted down the shaft by the falling burning dust that was lifted from the timbers on the sides of the shaft. Contributing causes of explosions often might be classified as a primary cause, as it is often impossible to differentiate between the true cause and the contributing cause of an explosion. In any event, it is evident that contributing causes are highly important, and they indicate the line of action that must be taken to reduce or eliminate explosion causes.

Early in the twentieth century considerable attention was given to blasting in Ohio coal mines because a number of windy or blown-out shots occurred and there was agitation at this time to prevent the misuse of explosives. The State legislature passed a law allowing the mine inspectors to curb the excessive use of explosives underground; following this, decided interest was manifested in "safe" explosives, which are now called "permissible." In 1912 not quite 3,000 pounds of this explosive was used and it was not until 1920 that an appreciable quantity was used. In that year more than 20 tons of permissible explosives were used in Ohio coal mines. However, it was not until 1925 that any considerable amount of permissible explosives was used; in that year more than 50 tons were sold to the coal mines in Ohio. Table 9 shows the class of explosives used in coal mines from 1912 to 1935; it appears that in 1935 the largest quantity of permissible explosives to date was used, more than 82 tons being supplied to coal mines. It is believed that this use of permissible explosives reduced materially the amount of dust formed and thereby the possibility of propagation of flame when mining was done where gas and dust existed, and it is unfortunate that all underground blasting in coal mines is not done with permissible explosives.

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TABLE 9. - Classes of explosives used in Ohio coal mines, 1912-35

Year	Black blasting powder		High explosives except permissibles, pounds	Permissible explosives, pounds
	Granular, kegs	Pellet, cases		
1912	266,647	-	160,400	2,975
1913	305,581	-	62,360	6,650
1914	192,097	-	547,700	11,200
1915	253,343	-	567,131	11,750
1916	364,760	-	96,330	5,926
1917	565,950	-	448,681	6,948
1918	519,006	-	855,501	13,806
1919	345,594	-	613,189	1,350
1920	662,374	-	861,417	41,366
1921	286,833	-	641,421	22,725
1922	452,154	-	1,065,768	4,050
1923	500,995	-	1,128,008	56,275
1924	319,241	-	466,898	44,850
1925	344,141	-	468,510	100,850
1926	371,672	-	694,035	115,325
1927	215,669	-	428,100	52,550
1928	244,959	-	305,925	73,850
1929	282,367	-	241,575	96,738
1930	119,096	111,032	127,014	155,800
1931	81,910	102,674	106,938	107,850
1932	77,059	67,268	294,424	149,475
1933	97,518	96,735	247,125	107,700
1934	113,075	104,479	268,151	142,450
1935	112,401	105,414	751,991	164,950

CAUSES OF GAS AND DUST ACCUMULATIONS

Approximately 86 percent of the explosions were caused by ignition of gas, and more than 90 percent of the explosions were classified as gas or gas and dust ignitions; if gas could be kept below the explosive limit, most of the coal-mine explosions in Ohio could be prevented.

The various causes outlined in table 10 are discussed in detail below.

Ventilation

Insufficient ventilation, not otherwise classified, was directly responsible for accumulation of gas in 10 explosions. It is probable that in most of the instances the lack of ventilation was due to improper coursing of air or fans of insufficient size and capacity or, in the early days to furnaces.

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TABLE 10. - Causes of gas and dust accumulations

Causes	No. of ignitions
Gas:	
Ventilation defects:	
Insufficient ventilation not otherwise classified	10
Fans:	
Fan stopped	11
Fan too small	1
Fan belt slipping (underground)	1
	13
Door open	6
Ineffective or damped furnace	2
Air short-circuited	2
Unventilated section	2
Entry idle	2
Ventilation obstructed	1
Brattice not advanced	1
No brattice	1
Fall	8
Feeder	5
Blasting	5
Dewatering shaft (75,000 cu. ft. per minute)	1
Cut into abandoned room	1
Cut into oil well	1
Fire (accumulation in fire area)	1
Total gas accumulations	62
Dust:	
Blasting	5
Dumping coal (surface)	1
Total dust accumulations	6
Total causes of accumulations reported	68

Fans

Fan difficulties or defects were responsible for gas accumulations in 13 explosions, in 11 of which the fan had stopped or had been stopped; in one instance the fan was too small to deliver sufficient or required ventilation, and in another slipping of the fan belt did not allow the fan to deliver enough air to keep the gas concentration below a dangerous percentage.

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Doors Left Open

In one instance a door was propped open, allowing gas to accumulate; in another men entered the mine on an idle day when no fireboss had been present and left the door open, causing an accumulation of methane; and in still another instance the mine was not thoroughly examined and an unnoticed open door allowed gas to accumulate. Another explosion, with 15 fatalities, resulted from ignition of gas that accumulated after a driver propped open one or more doors and caused a short circuit of the air. No preshift examination was made in one mine. Gas allowed to accumulate by a door that had been left open was ignited by an open light, causing an explosion that resulted in the death of 15 men. Most mining men realize that it is necessary to keep doors closed; on the other hand, however, catches or latches are provided in most bituminous-coal mines in the United States to make it easy for haulage crews to prop or latch open doors when they are going into a restricted area, which practice often permits accumulation of gas, ignition of which may be disastrous.

Ineffective or Damped Furnaces

In early days, when furnaces were used for ventilating purposes, ventilation was ineffective. Although only two ignitions were reported as due to accumulation of gas through ineffective or damped furnaces, there may have been a number of other explosions not listed under this cause.

Other Ventilation Failures

Other causes of gas accumulations from short-circuiting of the air by means other than doors left open were: Men entering unventilated sections; gas accumulated by lack of ventilation ignited by persons entering entries or sections of temporarily idle mines; occasional obstruction of air courses restricting if not entirely blocking ventilation in certain sections; and gas accumulation at face due to failure to advance or erect brattice.

Falls

In eight instances falls of roof released gas, which was ignited. Under this classification are included, also, cavities left in the roof by falls, in which gas accumulated.

Gas Feeders

Gas feeders are encountered generally during drilling or cutting, especially when faults are encountered. Five explosions resulted from ignition of gas "feeders" exposed during mining or drilling. In mines where falls are likely to be encountered a competent person should be present when coal is cut to test for gas with a flame safety lamp and to determine when feeders or dangerous quantities of gas are being released.

Feeders are released not only during cutting, but also frequently when coal is blasted; gas released under these conditions was ignited in five instances.

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Miscellaneous Causes

A pocket of gas occurred in a shaft in which 75,000 cubic feet of air per minute was delivered while the shaft was being dewatered; gas released when a machineman cut into an abandoned room was ignited by his open light; although he had been warned, a machineman cut into an oil well and ignited the oil; and gas that had accumulated in a fire area was ignited by the fire.

PRINCIPAL CAUSES OF DUST ACCUMULATION

One of the principal causes of accumulation of dust is blasting; this was particularly true in the earlier days of mining in Ohio, when the coal was shot off the solid or when only half of the coal was undercut. At one mine an accumulation of coal dust from dumping coal in the tipple was ignited by a nonpermissible-type motor.

RECOMMENDATIONS

The object of studying explosions in Ohio is to determine means for preventing the occurrence of similar explosions; therefore, recommendations made by investigators at the time of the explosions should serve as a basis of methods or means to be adopted to prevent such explosions. The recommendations and the number of times made in the reports from which this study was made are given in table 11.

Ventilation

The largest number of recommendations (38) was for improving ventilation. The outstanding recommendation under this heading was to provide new or larger fans on the surface, so that adequate quantities of air could be coursed to all faces in the mine. Improvement in ventilation without specifying how it should be obtained was recommended four times. To prevent leakage of air and to conduct it to the working places, it was recommended that masonry stoppings be built. It was recommended in three instances that the brattice be advanced to conduct the air directly to the working face. To course the air properly, it is necessary to have an intake and a return; therefore, a double-entry system was advocated following two explosions. Ventilation was obstructed in two mines, and it was recommended that such obstructions be removed from air courses. To reduce the area ventilated, it was recommended that abandoned mines or sections of mines be sealed. The main object of the recommendations appears to be to increase the quantity of air at the face and to keep it ventilated adequately at all times. It was recommended, therefore, that the quantity of air be increased, that the fan be run at a faster speed, or that the furnace be kept burning more rapidly; that the fan be run continuously; that ventilation engine and pipes be installed to ventilate relatively inaccessible sections; that repairs be made to stop leaks in the "walls"; that brattices be tightened; that partitions be installed in the shaft; and that break-throughs be provided in rooms at 30- and 60-foot intervals, staggering the crosscuts so

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TABLE 11. - Recommendations made

Recommendations	Times made
Ventilation:	
Install new or larger fan on surface	5
Improve ventilation	4
Build masonry stoppings	3
Advance brattice	3
Provide double-entry system	2
Remove obstructions from air course	2
Seal abandoned mine or workings	2
Increase quantity of air	1
Run fan faster	1
Keep furnace burning rapidly	1
Keep fan running continuously	1
Install ventilation engine and pipes	1
Repair shaft	1
Stop leaks in "walls"	1
Tighten brattices	1
Install partition in shaft	1
Provide break-through in rooms at 30 and 60 feet	1
Operate both fans	1
Place "check" on entry	1
Ventilate two rooms	1
Install automatic doors	1
Make haulage roads intakes	1
Eliminate doors	1
Use doors in pairs to form air lock	1
Total ventilation recommendations	38
Inspection and supervision:	
Make fireboss' examination before men enter	9
Stop operating mine	1
Withdraw men until shaft is sunk	1
Obey law	1
Employ fireboss	1
Pumper must carry flame safety lamp	1
Use flame safety lamp	1
Examine any section with flame safety lamp before entering with open light	1
Exercise care when approaching a fault	1
Men must not enter mine when fan is stopped	1
Provide two openings	1
Exert precautions along every line	1
Total inspection and supervision recommendations	20

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TABLE 11. - Recommendations made - Continued

Recommendations	Times made
Blasting:	
Use permissible explosives	2
Fire no shots in holes drilled on the solid	2
Undercut the coal	2
Employ shot firers	1
Reduce quantity of explosives	1
Limit charge of explosives	1
Last man on split must blast first	1
Total blasting recommendations	10
Dust control:	
Rock-dust thoroughly	3
Clean out dust	2
Sprinkle entries and room necks	2
Wet coal dust	1
Remove dust from tipple daily	1
Total dust-control recommendations	9
Electrical control:	
Use permissible electrical equipment	4
Use permissible electric cap lamps	1
Provide sectional switches	1
Total electrical control recommendations	6
Total recommendations	83

that they would not be opposite one another. In one instance it was recommended that both fans be run, whereas only one had been in operation previous to that time. To get ventilation into the rooms it was recommended that a "check" curtain be placed on an entry and that ventilation be carried up and into the rooms in virtually the same manner. It was recommended that automatic doors be installed in one mine to prevent short-circuiting of the air, and another recommendation was that haulage roads be made intake rather than return, as was the case before the explosion. Doors should be eliminated wherever possible, as doors may be left open or a large number may cause such leakage of the air that effective ventilation is impossible; it was recommended that doors be eliminated, but if they were used that they be erected in pairs to form air locks.

Inspection and Supervision

In twenty instances it was recommended that inspection and supervision be increased. The major recommendation, which was made nine times, was that fireboss' examinations be made before the men enter the mine.

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The officials at one mine knew so little about mining, and ventilation in particular, that it was recommended that the mine be closed. In another instance, because of inadequate ventilation, it was recommended that the men be withdrawn until a shaft was sunk. The terse recommendation, "Obey the law", was made in one instance. It was recommended that a fireboss be employed in one mine and that a pumper in another mine should carry a flame safety lamp to test for gas while making his rounds. At another mine it was necessary to recommend that a flame safety lamp be used; evidently such a lamp was on hand but was not being used. To minimize the hazard of entering a section with open lights, it was recommended that every section be examined with a flame safety lamp before men wearing open lights be allowed to enter. To decrease the hazard from a sudden outburst of gas, it was recommended that care be exercised in approaching a fault. Still other recommendations were that men must not enter the mine when the fan was stopped; that two openings be provided; and that precautions be taken along every line. A number of recommendations listed under ventilation might well come under inspection and supervision; however, classifications have been made to place the recommendations under whatever head appears to be the most appropriate.

Blasting

Ten recommendations were designed to reduce the explosion hazards in blasting. The use of permissible explosives was recommended only twice, the other recommendations bearing on the manner of preparing to fire and firing, presumably with black blasting powder or possibly dynamite. It was recommended twice that shot holes not be drilled on the solid and twice that the coal be undercut. Other recommendations were that shot-firers be employed; that the quantity of explosives be reduced; that the charge of explosive be limited; and that the last man on a split blast first in order that the fumes from blasting would not be carried over the other men still working. Methods for controlling the dust consist of making the dust non-explosive or removing it. It was recommended in three instances that the mine be rock-dusted thoroughly and in two that the dust be cleaned out and removed from the mine. It was recommended twice that the entries and room necks be sprinkled to keep down the dust and to keep it wet enough to prevent it from being raised in a cloud. Another similar recommendation was that the coal dust be made wet and that it be removed from tipples daily to prevent dangerous accumulations.

Electrical Control

Use of permissible electrical equipment was recommended four times and use of permissible electric cap lamps once. It was recommended that sectional switches be provided to cut off the power from any section of the mine when it was not working.

SUMMARY

The outstanding type of explosion was gas, 134 of the 163 explosions having been purely gas explosions. Nine explosions were due to dust, seven to gas and dust, five to powder smoke, one to oil, and seven were not desig-

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nated, but probably most of them were due to gas. Most of the explosions occurred in shaft mines (93 occurred in shafts); 23 occurred in drift mines, 18 in slope mines, and 29 were undesignated. The largest number of deaths (151) resulted from explosions in shaft mines. Twelve occurred in the 23 explosions in drift mines and only seven deaths occurred in the 18 explosions in slope mines. The largest number of explosions occurred in Athens, Belmont, Columbiana, Guernsey, Jackson, and Jefferson Counties. The largest number of fatalities occurred in Athens County and the second largest in Jefferson County. Forty one persons were injured in Belmont County, the largest number listed as having been injured in explosions in any county in the State.

The coal-mine-explosion fatality rates ranged from 0.038 death per million tons in the 10-year period 1884-93, to 0.440 death per million tons in 1924-33. There were no explosions and no explosion fatalities in 1932, 1933, 1934, and 1936. The fatality rates from explosions per million man-hours ranged from 0.010 in 1884-93 to 0.253 in 1924-33. Coal-mine deaths from explosions in Ohio ranged from 1.08 percent of all coal-mine fatalities in 1914-23 to 12.31 percent in 1924-33; in other words, in the 10-year period ended 1933, more than 12 of every 100 coal-mine deaths were caused by explosions.

Open flames caused the largest number of deaths, open lights causing 91 explosions, flame safety lamps 1, furnace fires 1, and matches 1, a total of 94 (57.67 percent of all of the ignitions); blasting was second with nine explosions (5.56 percent of the total); electricity was third with six explosions (3.68 percent of all ignitions); and fires were fourth with four ignitions (2.46 percent of all ignitions).

Open lights caused 0 to 84 percent of all explosions in the 10-year period from 1874 to 1936, except that from 1917 to 1936, open lights caused as many or more explosions than any other cause. Blasting caused 0 to 14.29 percent and electricity 3.85 to 28.57 percent of the explosions during the above-mentioned 10-year periods.

Factors contributing to causes of explosions were defective ventilation, blasting, ineffective or no fireboss examinations, brushing out gas, men going over falls wearing open lights, and failure of officials to observe rules. A large number of explosions could be attributed to failure on the part of officials to provide safe working places for the men.

The outstanding causes of gas accumulations that resulted in explosions were insufficient ventilation, fans stopped, or improper working conditions. Open doors, short-circuited air, and improper or nonventilation of sections of the mines were the principal causes of gas accumulations. Falls frequently have released bodies of gas in coal mines, and gas feeders released during cutting or blasting of coal have been a prolific source of dangerous quantities of gas. Blasting of coal has been one of the chief causes of dust accumulation and has also contributed heavily to release of explosive gas.

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The United States Bureau of Mines, through its Mine Safety Board, has issued a number of recommendations for increasing safety in mines, a number of which are designed primarily to prevent coal-mine explosions. These recommendations are given in Information Circular 6946, a copy of which may be obtained from the United States Bureau of Mines. These and other recommendations by engineers of the Bureau indicate that accumulations of explosive quantities of gas in coal mines can be eliminated or greatly reduced by maintaining an adequate quantity, quality, and velocity of the air. The air must be coursed properly by providing, first, a sufficient quantity of air, and then conducting it to the working place with as little loss as possible. Overcasts should be used instead of doors wherever possible and they, as well as stoppings, should be constructed of fire-resistant, airtight material. Line brattices should be used at the working faces beyond the last crosscut, so that a definite velocity of air is made to sweep the face of the working place at all times. It is believed that at least 100 feet of air per minute should sweep the working face. In case there is a sudden outburst of gas, the ventilating current may carry it away. It is much safer and more efficient to have the return air current in a special airway and not on trolley or haulage roads or other places where machinery is used, in order that no source of ignition may be present in the return airways and that men or animals may not be subjected to poisonous gases in case of fire or explosion.

The sources of ignition can be removed in large part by using only permissible electrical machinery for hauling, drilling, undercutting, and loading the coal. Another source of ignition will be removed if permissible electric cap-lamps are substituted for open lights in all coal mines, whether they are considered gassy or nongassy. Explosives should be permissible brands used in a permissible manner to eliminate the explosion hazard that is present with other high explosives or black blasting powder. Finally, when all precautions have been taken to prevent the accumulation of methane and remove sources of ignition, it is necessary to see that the equipment and the ventilating system are maintained in proper condition at all times. Adequate supervision is necessary, and to insure this each underground official should have not more than 25 men under his supervision; or, at least the men should be so concentrated that a foreman or assistant foreman may visit every working place at least every two hours, preferably hourly.

Care should be taken to examine all electrical equipment and installations at regular intervals, and at less frequent intervals a very rigid examination should be made to determine the safety of the equipment.

Application of these basic principles of safety should help materially to reduce or to eliminate explosions in Ohio coal mines.

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